Energy Mines and Resources Canada | Energie Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

COMPARISON OF RADON (AND THORON) DAUGHTER MEASUREMENTS BY AN AUTOMATED, PROGRAMMABLE, GRAB-SAMPLER WITH 'CONVENTIONAL' GRAB-SAMPLING

J. BIGU AND M. GRENIER

ELLIOT LAKE LABORATORY

AUGUST 1982

This document is an unedited interim report prepared primarily for discussion and internal reporting purposes. It does not represent a final expression of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport [illegible] rédigé [illegible] de documentation [illegible] nulle-ment [illegible] définitive de [illegible] Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

MICROMEDIA

OCT 27 1982

38pp

MINERALS RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT MRP/MRL 82-75(TR)

COMPARISON OF RADON (AND THORON) DAUGHTER MEASUREMENTS BY AN AUTOMATED, PROGRAMMABLE, GRAB-SAMPLER WITH 'CONVENTIONAL' GRAB-SAMPLING

by

J. Bigu* and M. Grenier**

ABSTRACT

A technical evaluation of an automated, programmable, grab-sampler manufactured by Pylon Instruments under the commercial name WL-1000C has been conducted. Measurements were carried out under laboratory-controlled conditions in a large 'radon-room' designed for calibration purposes, and at an underground uranium mine. Data obtained with the WL-1000C have been compared with conventional grab-sampling using several methods (e.g., Kusnetz, Thomas-Tsivoglou and Markov methods) and with a continuous radon daughter monitor manufactured by EDA and a semi-continuous Working Level Meter manufactured by Harshaw. Tests were done under constant radiation conditions and also under rapidly fluctuating conditions in order to determine the response of the instrument in these two cases of practical interest. The Working Level (WL) used in these experiments was in the approximate range of 0.01 to 10 WL. The results obtained were quite satisfactory taking into account the conditions of the tests. A number of suggestions are made to further improve the performance of the instrument.

---

* Research Scientist and Radiation Project Leader, ** Physical Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario, Canada.

CONTENTS

	Page
ABSTRACT	i
INTRODUCTION	1
DESCRIPTION OF THE INSTRUMENT	3
EXPERIMENTAL PROCEDURE	4
EXPERIMENTAL RESULTS AND DISCUSSION	5
CONCLUSIONS	26
ACKNOWLEDGEMENTS	31
REFERENCES	31

FIGURES

No.

1. WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and Rolle methods) and grab-sampling by the Markov method. Also shown are the results obtained with the Harshaw-WLM and the EDA WLM-300. Experiments carried out in a radon room 6
2. WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and Rolle methods) and grab-sampling by the Markov method, and the Kutnetz method. Also shown are data obtained with the Harshaw-WLM. Experiments were carried out in a radon room 7
3. RaA concentration versus time for the WL-1000C (Rn α-spectroscopy) and grab-sampling by the Markov method. Also shown is [RaA] obtained with the Harshaw-WLM. Experiments were carried out in a radon room 8
4. RaB concentration versus time for the WL-1000C (Rn α-spectroscopy) and Harshaw-WLM. Experiments were carried out in a radon room ... 9
5. RaC concentration versus time for the WL-1000C (Rn α-spectroscopy) and the Harshaw-WLM. Measurements were carried out in a radon room 10
6. RaA concentration versus time for the WL-1000C (Rn α-spectroscopy) and the Markov method. Measurements were carried out in a radon room 11
7. WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and Rolle method), and the Markov method, and the EDA WLM-300. Measurements were carried out in a radon room 12
8. WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and Rolle method) and Markov method and the EDA WLM-300. Measurements were carried out in a radon room 13
9. WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, Rolle method and Kusnetz method), the Markov method and the EDA WLM-300. Measurements were carried out in a radon room 14

10. WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and grab-sampling by the Thomas-Tsivoglou method. Measurements were carried out in an underground uranium mine 15

11. RaA concentration versus time for the WL-1000C (Rn α-spectroscopy, Rn/Tn α-spectroscopy and Thomas-Tsivoglou method) and grab-sampling by the Thomas-Tsivoglou method. Measurements were carried out in an underground uranium mine 16

12. RaB concentration versus time for the WL-1000C (Rn α-spectroscopy, Rn/Tn α-spectroscopy and Thomas-Tsivoglou method) and grab-sampling by the Thomas-Tsivoglou method. Measurements were carried out in an underground uranium mine 17

13. RaC concentration versus time for the WL-1000C (Rn α-spectroscopy, Rn/Tn α-spectroscopy and the Thomas-Tsivoglou method) and grab-sampling by the Thomas-Tsivoglou method. Measurements were carried out in an underground uranium mine 18

14. WL(Tn) versus time for the WL-1000C (Rn/Tn α-spectroscopy) and grab-sampling. Measurements were carried out in an underground uranium mine 19

15. ThB concentration versus time for the WL-1000C (Rn/Tn α-spectroscopy) and grab-sampling. Measurements were carried out in an underground uranium mine 20

16. Experimental ratio [RaC]/[RaA] versus experimental ratio [RaB]/[RaA] obtained with the WL-1000C (Rn α-spectroscopy) and the Thomas-Tsivoglou method on a graph showing the theoretical limiting boundaries of three mine models: the mine tunnel, the isolated system, and a mine model consisting of the mixing of 'young' and 'old' air..... 21

17. Experimental ratio [RaA]/WL(Rn) versus experimental ratio [RaB]/WL(Rn) obtained with the WL-1000C (Rn α-spectroscopy) and the Thomas-Tsivoglou method on a graph showing the theoretical limiting boundaries of the above ratios for the isolated mine model. Also shown on the right hand side are the ages of air corresponding to the theoretical ratios 22

18. Theoretical ratio WL(Tn)/WL(Rn) versus age of air for the mine tunnel model and the isolated model..... 23

TABLES

1. Summary of some grab-sampling radiation data (daily average) obtained during 5 day-shifts in an underground uranium mine 27

2. Summary of some meteorological data (daily average) obtained during 5 day-shifts in an underground uranium mine 28

INTRODUCTION

Adequate mine air quality control is attained by monitoring radiation levels. Proper radiation monitoring prevents unnecessary risk to occupational workers. α- and γ-radiation monitoring is common in uranium mines and the uranium milling industry. However, unless high grade ores are mined and processed, only α-radiation usually needs to be considered. The α-radiation variable of interest is in most cases the Working Level (WL), a measure of the α-energy emitted by the radon gas progeny.

Radiation monitoring is essentially of two kinds: grab-sampling and continuous monitoring.

In the grab-sampling method an air sample is taken and the radiation level is determined. Most of the experimental methods that have been developed for the determination of the WL involve the measurement of α-particles from either RaA or RaC' or both (1 to 8). However, techniques based on β-particle count have also been investigated and applied (9 to 12). Relatively simple techniques involving a single total α- or β-count are commonly used when the only radiation variable of interest is the WL (1 to 5, 10, 11). Other more sophisticated techniques based on several α-counts enable the calculation of the radon daughters concentrations in addition to the WL (7,8).

The Kusnetz (2,3), Markov (1) and Rolle (4,5) methods, based on a single total α-count, and the β-particle method, e.g., (10), based on a single total β-count, permit a simple determination of the WL. A more accurate determination of the WL, in addition to the calculation of the concentration of the radon decay products, is possible if use is made of other more sophisticated techniques, such as the Tsivoglou method (7), the Thomas method (8) or some α-spectrometric methods (13,14,15). Furthermore, instrumentation and concepts have been developed that allow the determination of the WL to be

made in a matter of a few minutes. The instruments are commonly known as Instant Working Level Meters (IWLM). Evans and Schroeder (16) and later Groer (17), Rolle (18), Hill (19) and James and Strong (20) must be credited with the early development of the concept or basic instrumentation that has led to the design of several IWLM prototypes (see also ref. 21). A summary of radiation instrumentation for underground environments has been given by Bigu elsewhere (22).

The need for a simple, fast and reliable method for the routine determination of WL by a small-sized, automated instrument capable of performing the sampling, counting and raw data processing operations with minimum attendance has been sought for a long time. In addition, it would be highly desirable that the instrument be easily portable, light, electronically reliable, rugged and dust- and moisture-proof as its use is intended for harsh environmental conditions.

Pylon Instruments (Ottawa) has recently developed a microprocessor-controlled Working Level monitor, commercially available under the trade name WL-1000C, capable of determining the concentrations and WL of the radon progeny by several methods. Furthermore, the instrument permits the determination of the thoron progeny in addition to the radon progeny by using an α-spectroscopy method (15,23). The different methods available in the instrument can easily be selected by means of a keyboard. The WL-1000C only necessitates manual positioning of the sample, i.e., filter, in the sampling head and transfer of the sample from the sampling head to the detector system when the sampling period is over. The rest of the operational procedure is fully automatic, including the sampling period.

This report pertains to a technical evaluation of the WL-1000C under controlled laboratory conditions and in an underground uranium mine.

DESCRIPTION OF THE INSTRUMENT

The WL-1000C is approximately 6.8 kg in weight and has the following dimensions: 34.5 cm height, 30 cm width and 19 cm depth. The instrument is divided into two main sections. The lower section contains the instrument power supply consisting of several rechargeable Ni-Cd batteries. The upper section houses a silicon-barrier α-detector as well as a microprocessor and associated electronics. Sampling of air is done by means of a sampling pump/sampling head unit connected to the upper section of the WL-1000C by means of a cable approximately 1 m in length. The instrument uses special filters mounted on plastic cards, thereby eliminating the use of tweezers and simplifying considerably the handling of samples.

Several methods for determining the radiation variables of interest are programmed into the microprocessor. A total of six methods are available on command. They are: two α-spectroscopy methods; one of the methods permits determination of the radon daughter progeny, while the second method allows the determination of radon daughter/thoron daughter mixtures (15,23); two Kusnetz methods, one of which is a shorter version of the conventional method (2,3,23); the Rolle method (4,5), and the Thomas-Tsivoglou method (6,7,8). Also available is a short calibration routine which can be used to determine the instrument's detector α-counting efficiency, ε, and to verify the alignment of energy discriminators for the α-spectroscopy methods.

The WL-1000C is provided with a RS-232 interface output which allows transfer of data from the instrument to an external printer. In addition, the signal from the instrument, i.e., the α-spectrum of the radon and thoron progenies deposited on the filter during sampling can be studied using an external multichannel analyzer.

EXPERIMENTAL PROCEDURE

The WL-1000C was tested in the laboratory and in an underground uranium mine. All methods programmed into the instrument were tested and compared with independent grab-sampling by conventional methods, e.g., Thomas-Tsivoglou, Markov and Kusnetz methods, and with two radon daughter continuous monitoring systems.

The instrument was tested in 'pure' radon daughter atmospheres and in radon daughter/thoron daughter mixtures. Laboratory experiments were mainly conducted in a large radon room designed for calibration purposes. The radiation levels used ranged from less than 0.02 WL to about 10 WL. Underground WL's were in the 0.2-0.5 range.

A series of laboratory measurements were initially conducted using factory values for the detector α-counting efficiency and pump flow rate. The results obtained with these values were not in good agreement with grab-sampling measurements, thus the detector and sampling pump were calibrated for α-counting efficiency and flow rate, respectively according to procedures described elsewhere (24). The data presented in this report were obtained with the new calibration factors.

The WL-1000C was tested under constant and rapidly fluctuating radiation conditions. This was aimed at comparing the time response of grab-sampling instruments, e.g., the WL-1000C, versus continuous monitoring systems. A Working Level Monitor operating on time integrating principles manufactured by EDA Instruments, and known under the commercial name of WLM-300, and a radon daughter-WL semi-continuous system manufactured by Harshaw instruments, under the commercial name of Radon Daughter Detector Model 101 and Radiation Computer Model 100, were also used in the tests. For simplicity, the Harshaw system will be referred to hereafter as the Harshaw-WLM.

EXPERIMENTAL RESULTS AND DISCUSSION

Figures 1 to 9 show experimental data for the radon daughter Working Level, WL(Rn), and the concentrations of RaA, RaB and RaC, say [RaA], [RaB] and [RaC], obtained in a large 'radon room' designed for calibration purposes. These graphs compare the values of the above variables as obtained by different instruments, such as the Harshaw-WLM and the EDA WLM-300, in addition to the Pylon WL-1000C, and several grab-sampling methods including the Markov and Kusnetz methods.

Figures 10 to 15 show experimental data for WL(Rn), WL(Tn), [RaA], [RaB], [RaC] and [ThB] obtained in an underground uranium mine. As in the case of Fig. 1 to 9, several methods and instruments were compared.

Figures 16 and 17 show, respectively, the ratio [RaB]/[RaA] versus [RaC]/[RaA] and WL(Rn)/[RaA] versus WL(Rn)/[RaB]. Also shown in the graphs are the theoretical limiting boundaries for the same ratios (4,5,10,25,26,27) for several mine models: the mine-tunnel model, the isolated model and a model consisting of the mixing of 'old' and 'young' air. The isolated mine model is defined as one in which a certain quantity of radon gas is added initially to pure air and then decays, there being no replenishment or removal of activity from the system. In the mine tunnel model a source of radon is released at one point in the mine and then carried along with the ventilation air through the rest of the mine. The radon gas is constantly replenished by diffusion from the walls of the mine. Figures 16 and 17 permit the calculation of the age of mine air according to the mine model used.

Figure 18 shows the theoretical ratio WL(Tn)/WL(Rn) versus age of mine air for the mine tunnel model and the isolated model. Also shown in the graph is the range of experimental values for the ratio WL(Tn)/WL(Rn) and the range of theoretical ages of mine air calculated by means of Fig. 16 and 17

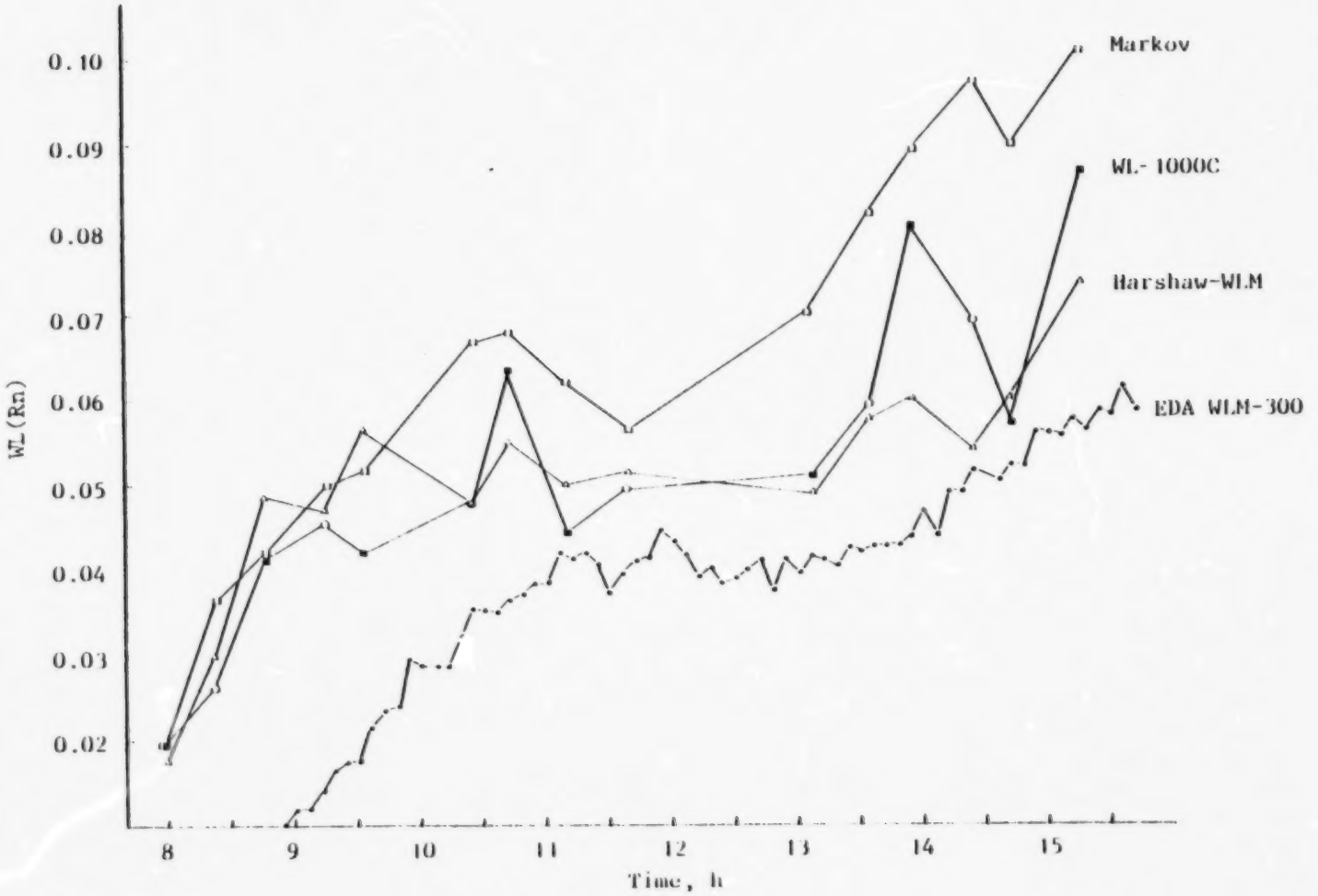

Fig. 1 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and Rolle methods) and grab-sampling by the Markov method. Also shown are the results obtained with the Harshaw-WLM and the EDA WLM-300. Experiments carried out in a radon room.

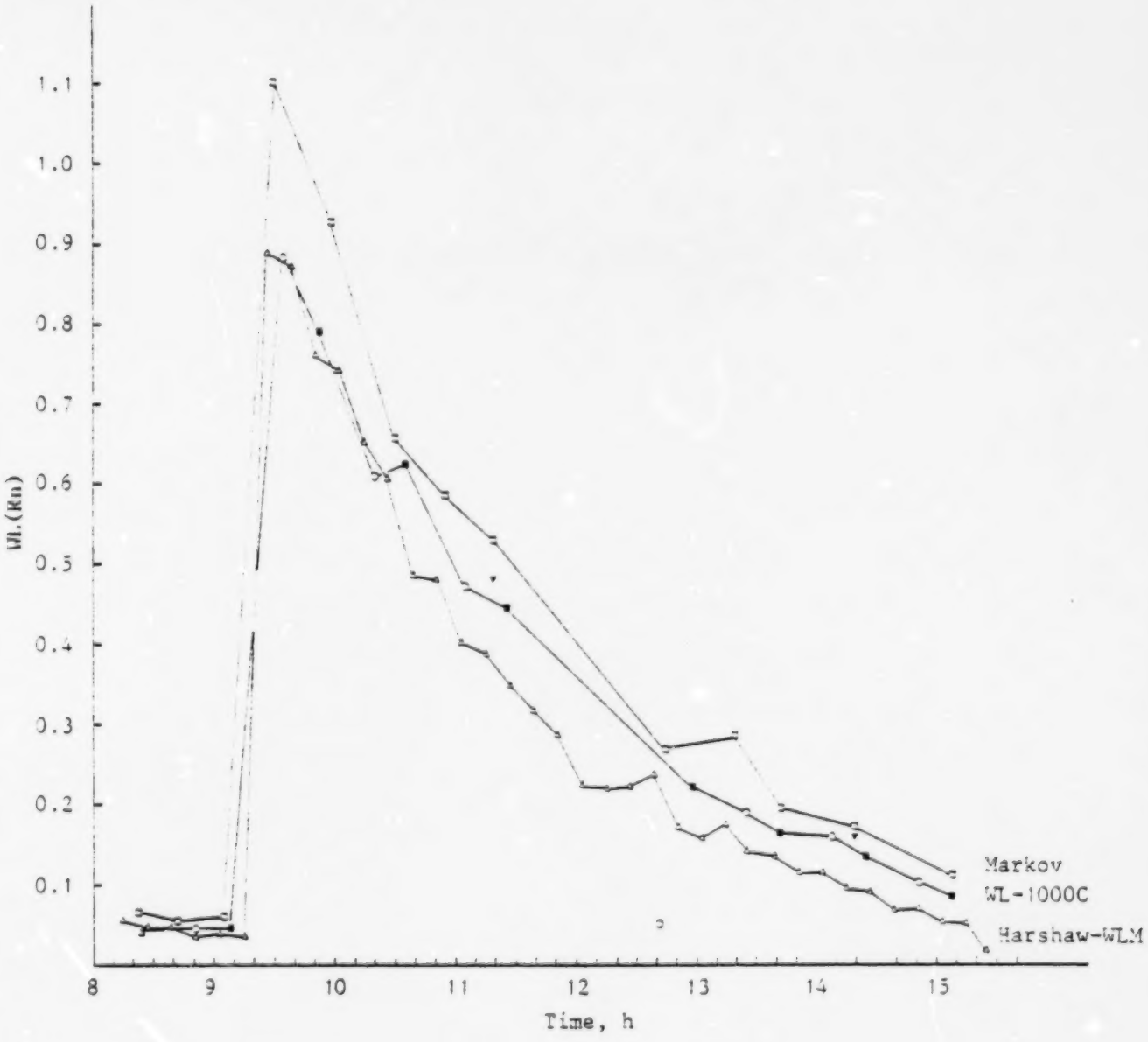

Fig. 2 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy and Rolle methods) and grab-sampling by the Markov method, and the Kusnetz method (▲). Also shown are data obtained with the Harshaw-WLM. Experiments were carried out in a radon room.

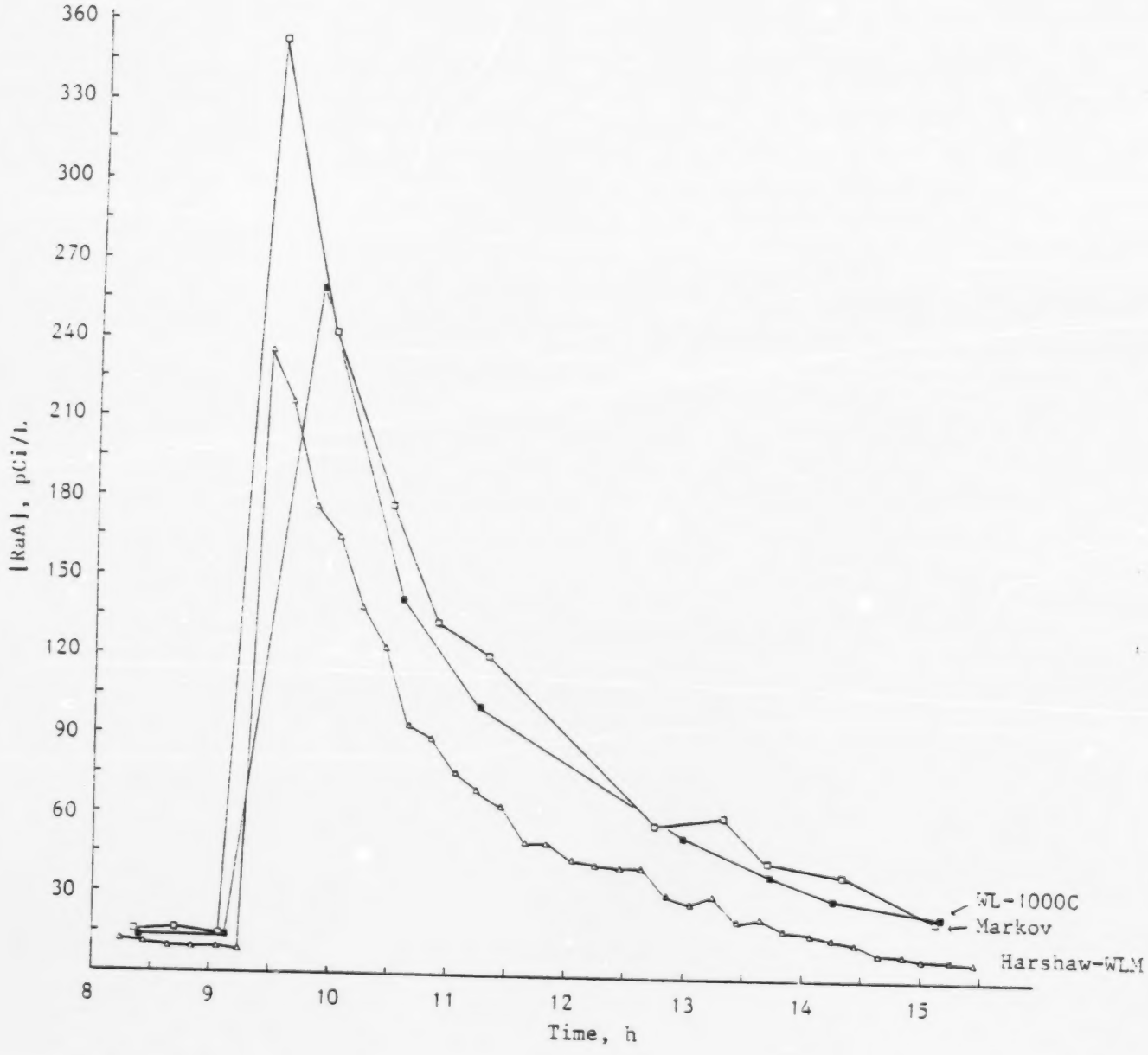

Fig. 3 - RaA concentration versus time for the WL-1000C (Rn α-spectroscopy) and grab-sampling by the Markov method. Also shown is [RaA] obtained with the Harshaw-WLM. Experiments were carried out in a radon room. (Note: 1 pCi = 3.7 x 10^{-2} Bq).

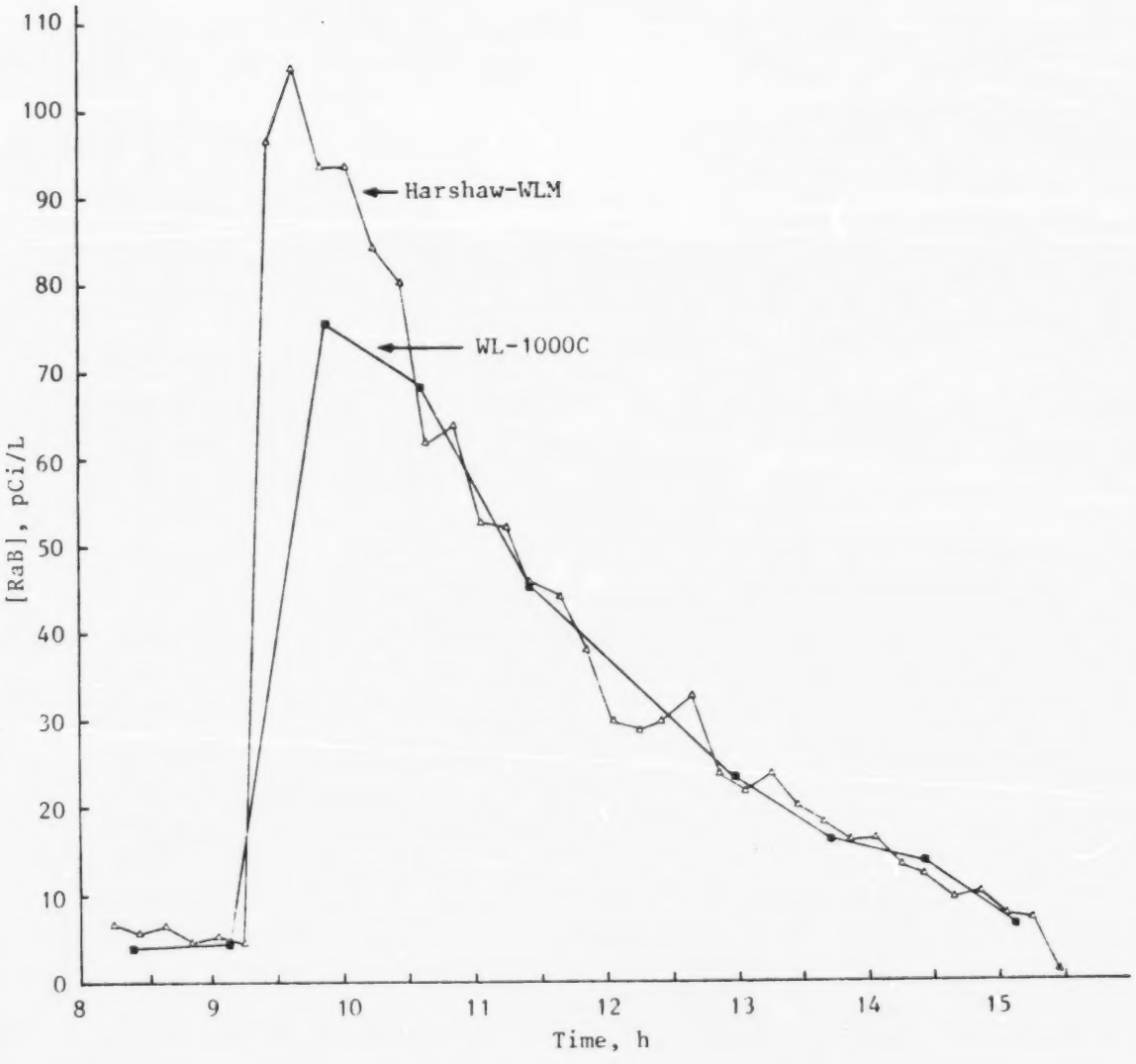

Fig. 4 - RaB concentration versus time for the WL-1000C (Rn α-spectroscopy) and Harshaw-WLM. Experiments were carried out in a radon room.

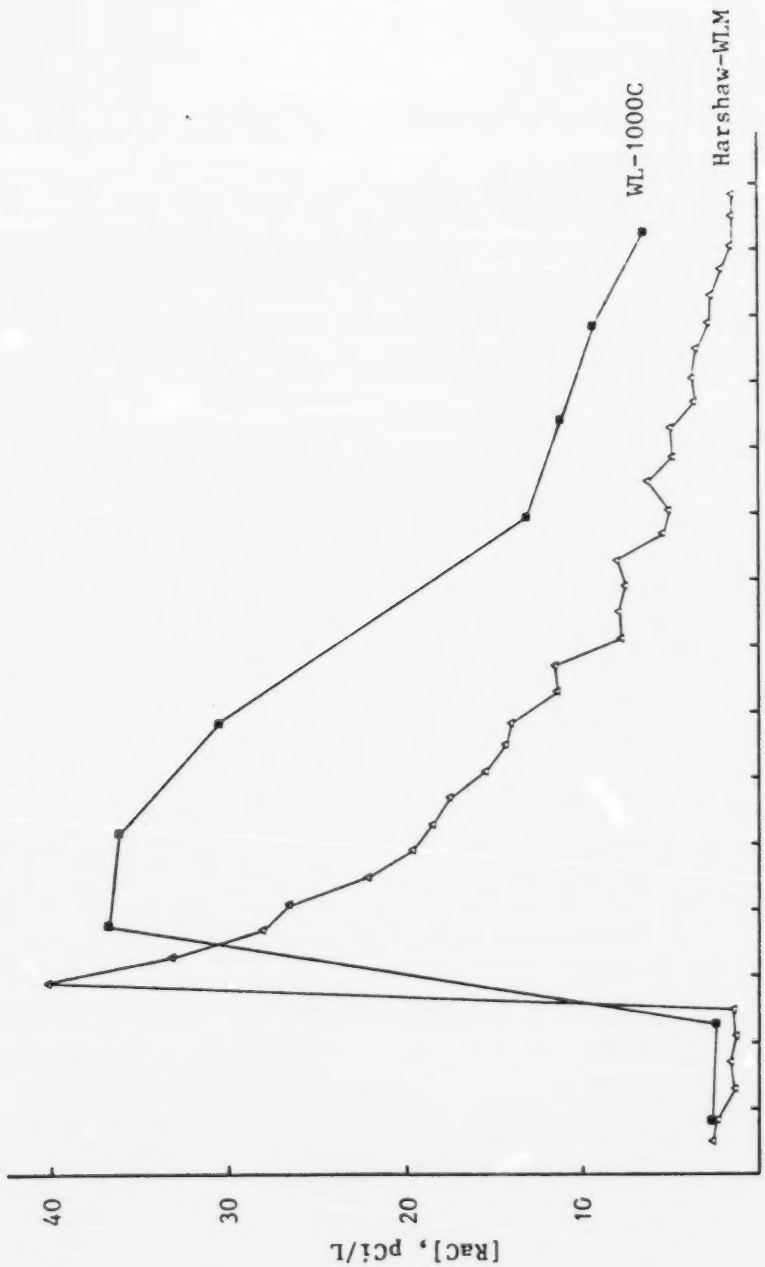

Fig. 5 - RaC concentration versus time for the WL-1000C (Rn α-spectroscopy) and the Harshaw-WLM. Measurements were carried out in an underground uranium mine.

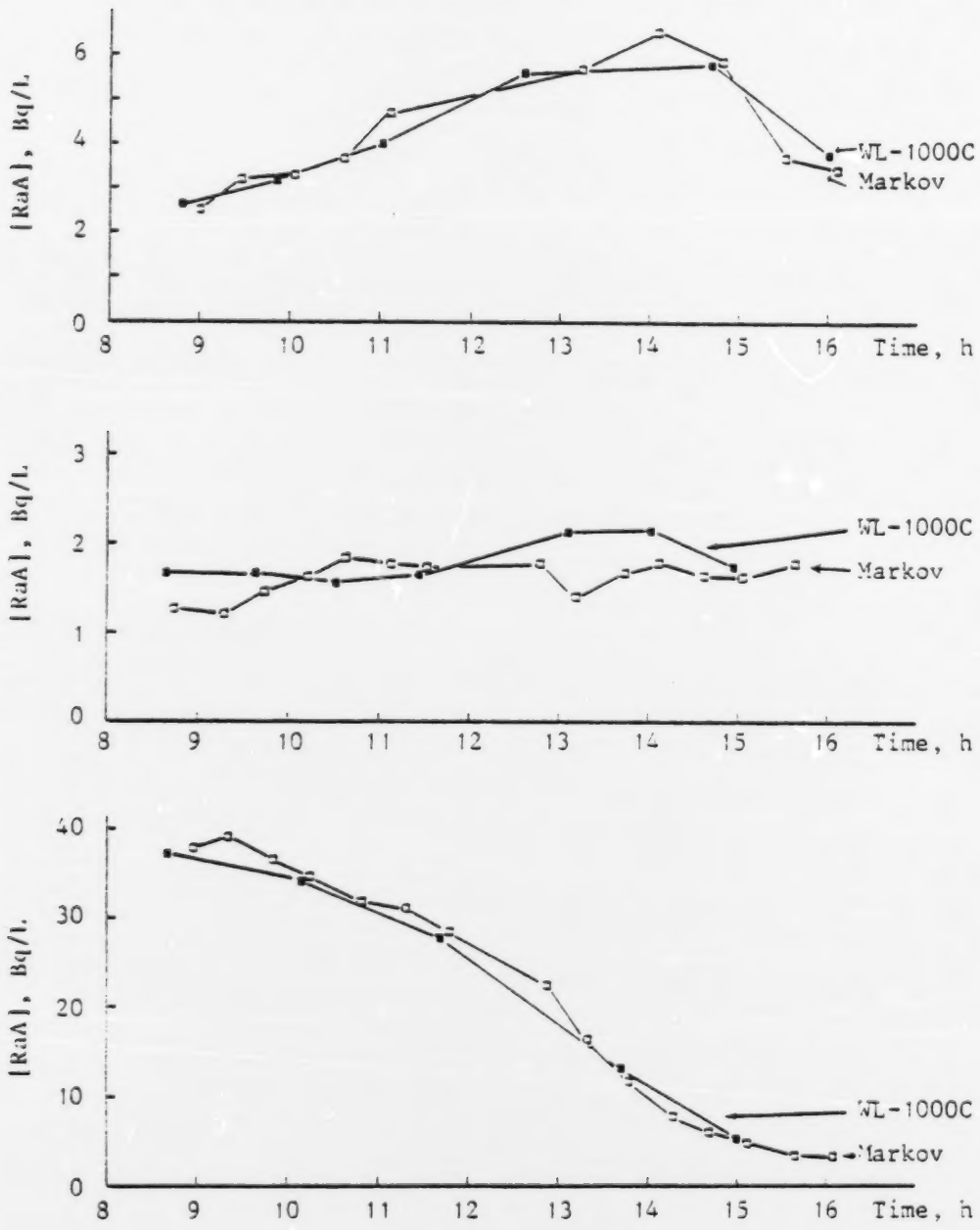

Fig. 6 - RaA concentration versus time for the WL-1000C (Rn α-spectroscopy) and the Markov method. Measurements were carried out in a radon room.

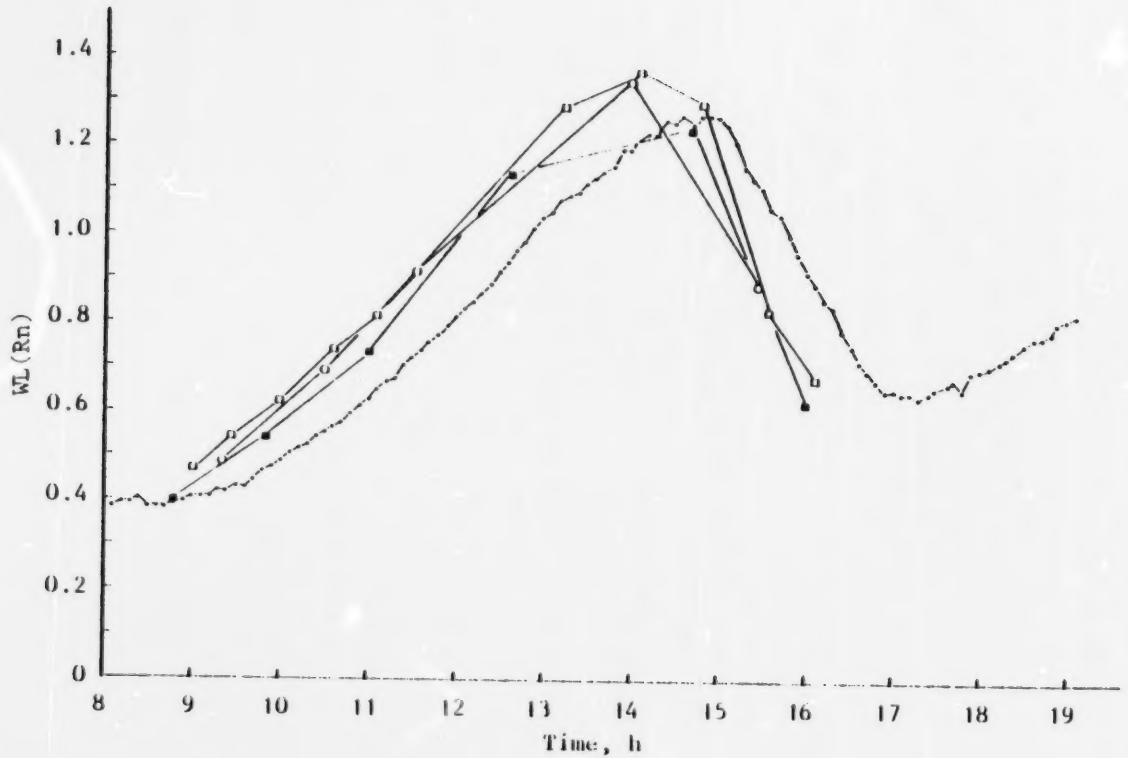

Fig. 7 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-, and Rolle method, -o-), the Markov method, -□-, and the EDA WLM-300 (-·-). Measurements were carried out in a radon room.

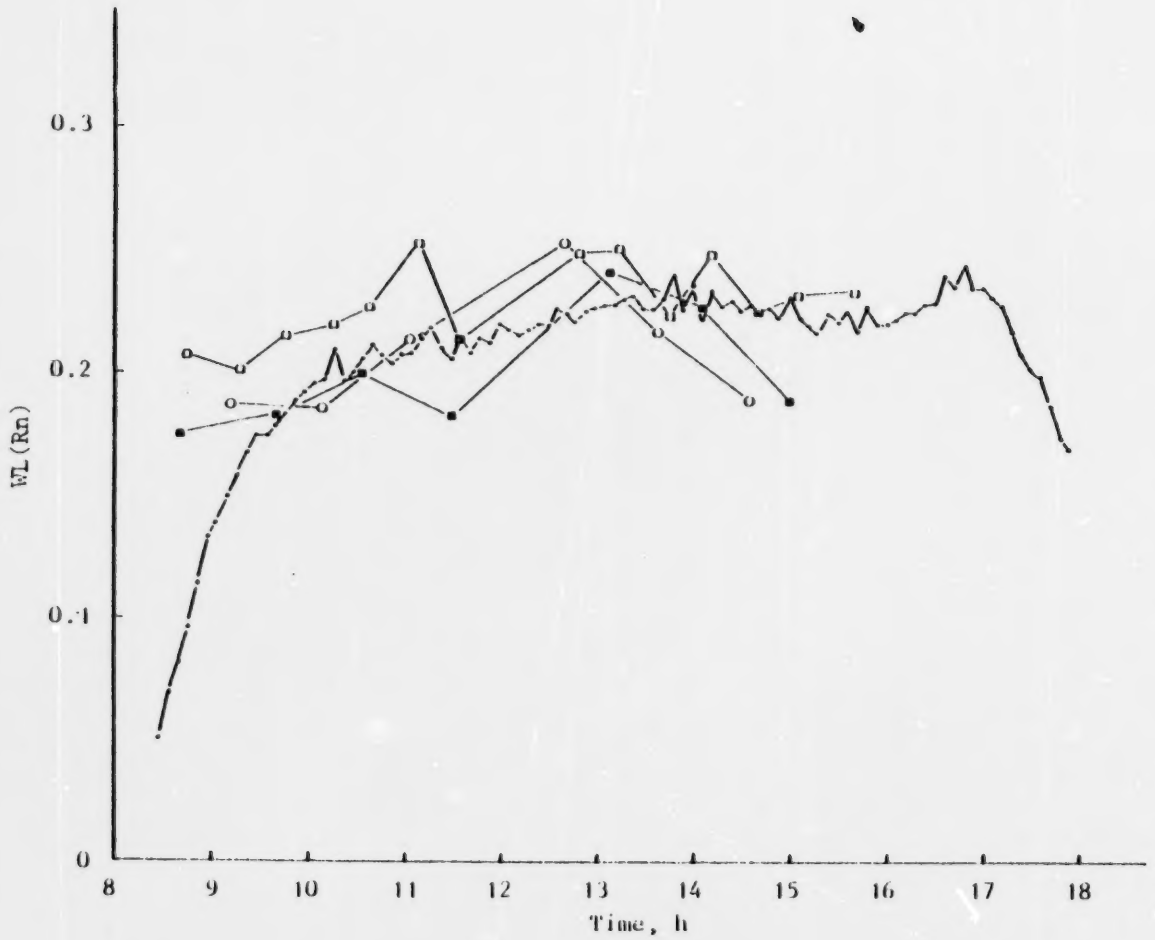

Fig. 8 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rolle method, -o-), the Markov method (-□-) and the EDA WLM-300 (-·-). Measurements were carried out in a radon room.

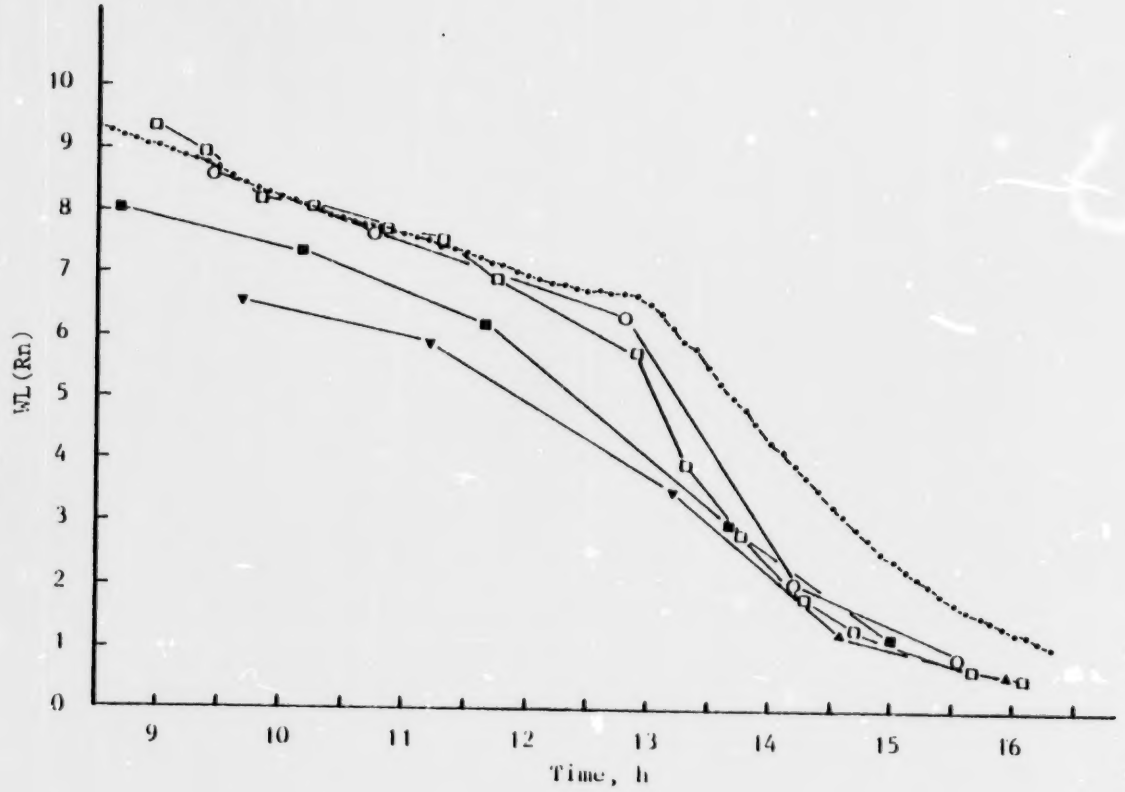

Fig. 9 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rolle method, -o-, and Kusnetz method, -▲-), the Markov method (-□-) and the EDA WLM-300 (-·-). Measurements were carried out in a radon room.

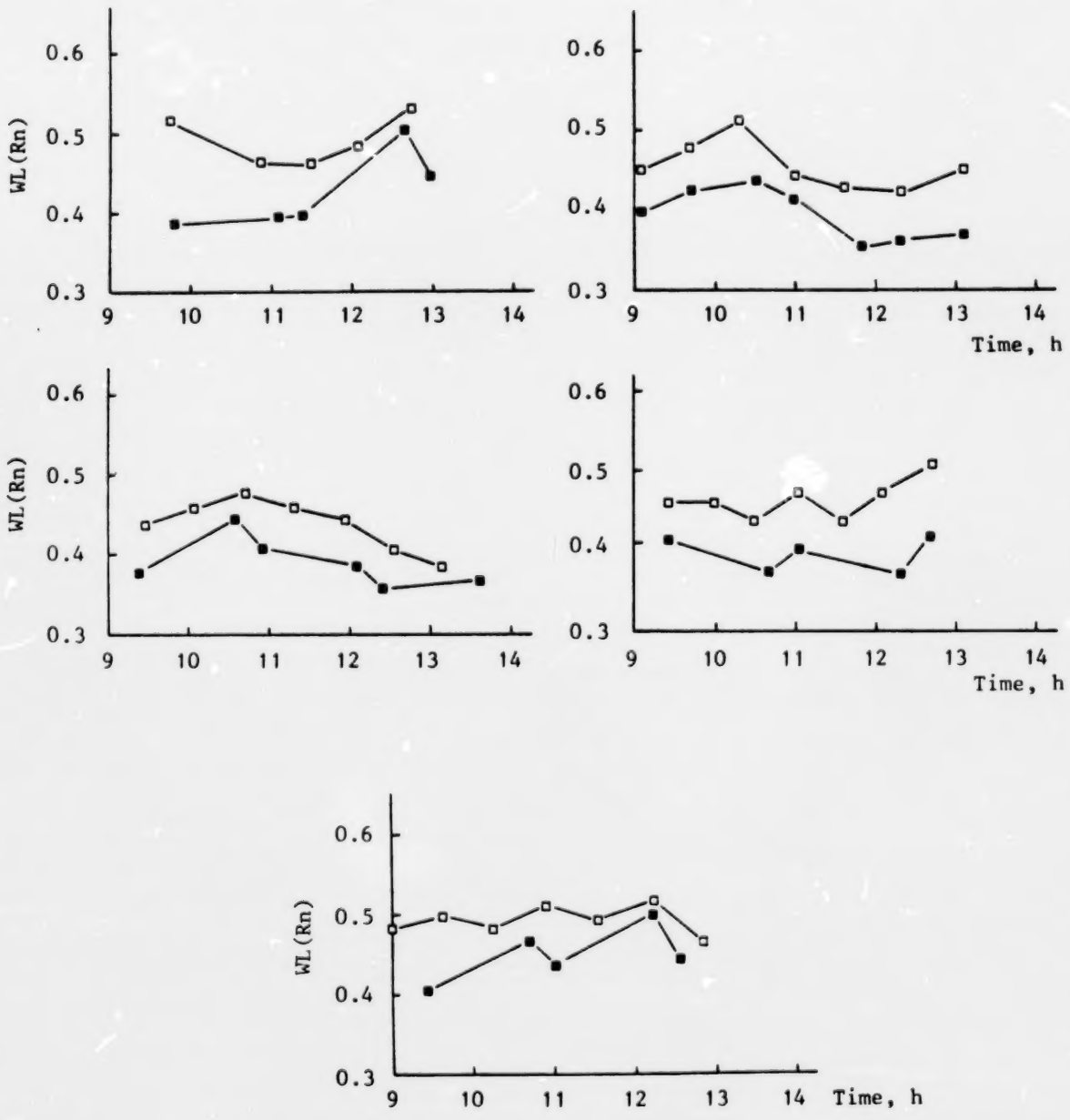

Fig. 10 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-), and grab-sampling by the Thomas-Tsivoglou method, -□-. Measurements were carried out in an underground uranium mine.

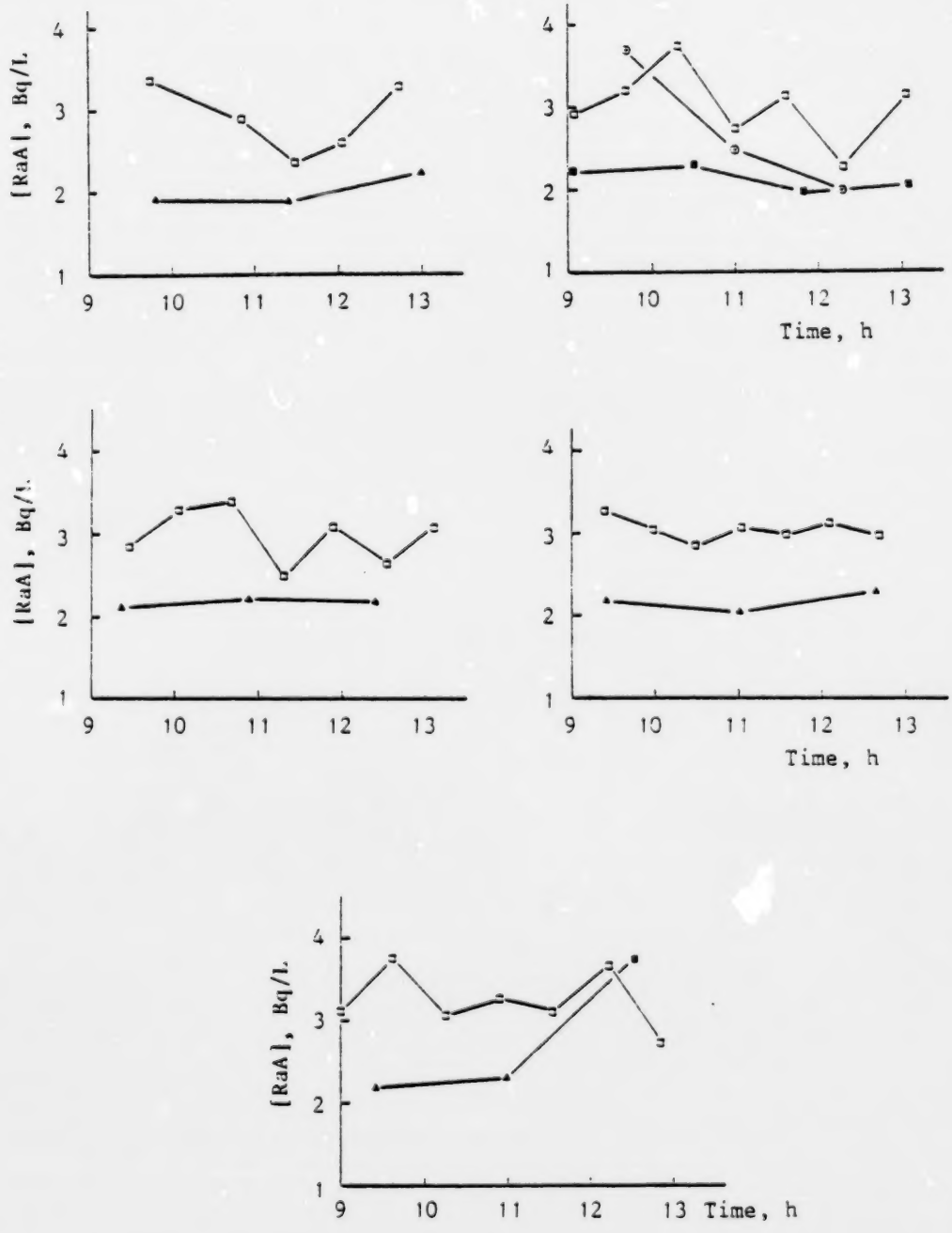

Fig. 11 - RaA concentration versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rn/Tn α-spectroscopy, -▲-, and Thomas-Tsivoglou method, -⊙-) and grab-sampling by the Thomas-Tsivoglou method (-□-). Measurements were carried out in an underground uranium mine.

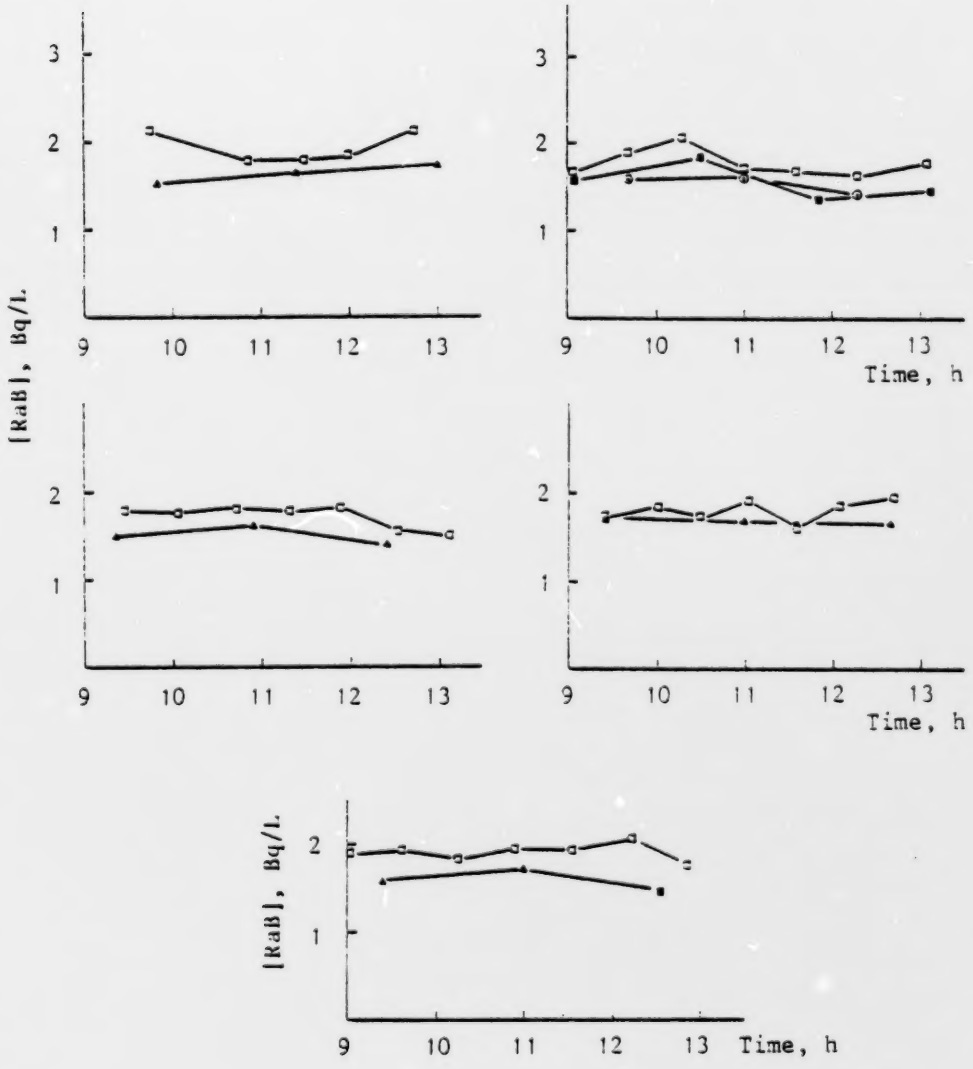

Fig. 12 - RaB concentration versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rn/Tn α-spectroscopy, -▲-, and Thomas-Tsivoglou method, -⊙-) and grab-sampling by the Thomas-Tsivoglou method (-□-). Measurements were carried out in an underground uranium mine.

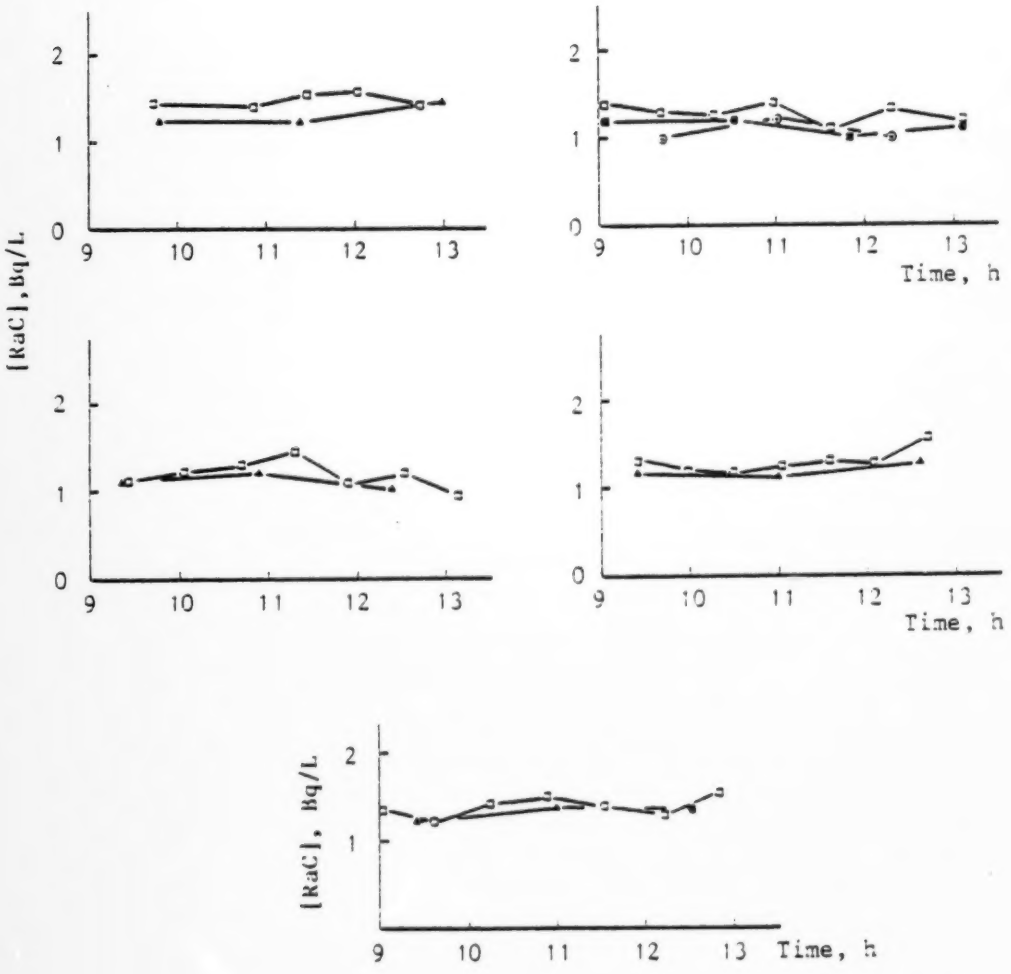

Fig. 13 - RaC concentration versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rn/Tn α-spectroscopy, -▲-, and the Thomas-Tsivoglou method, -⊙-) and grab-sampling by the Thomas-Tsivoglou method, (-□-). Measurements were carried out in an underground uranium mine.

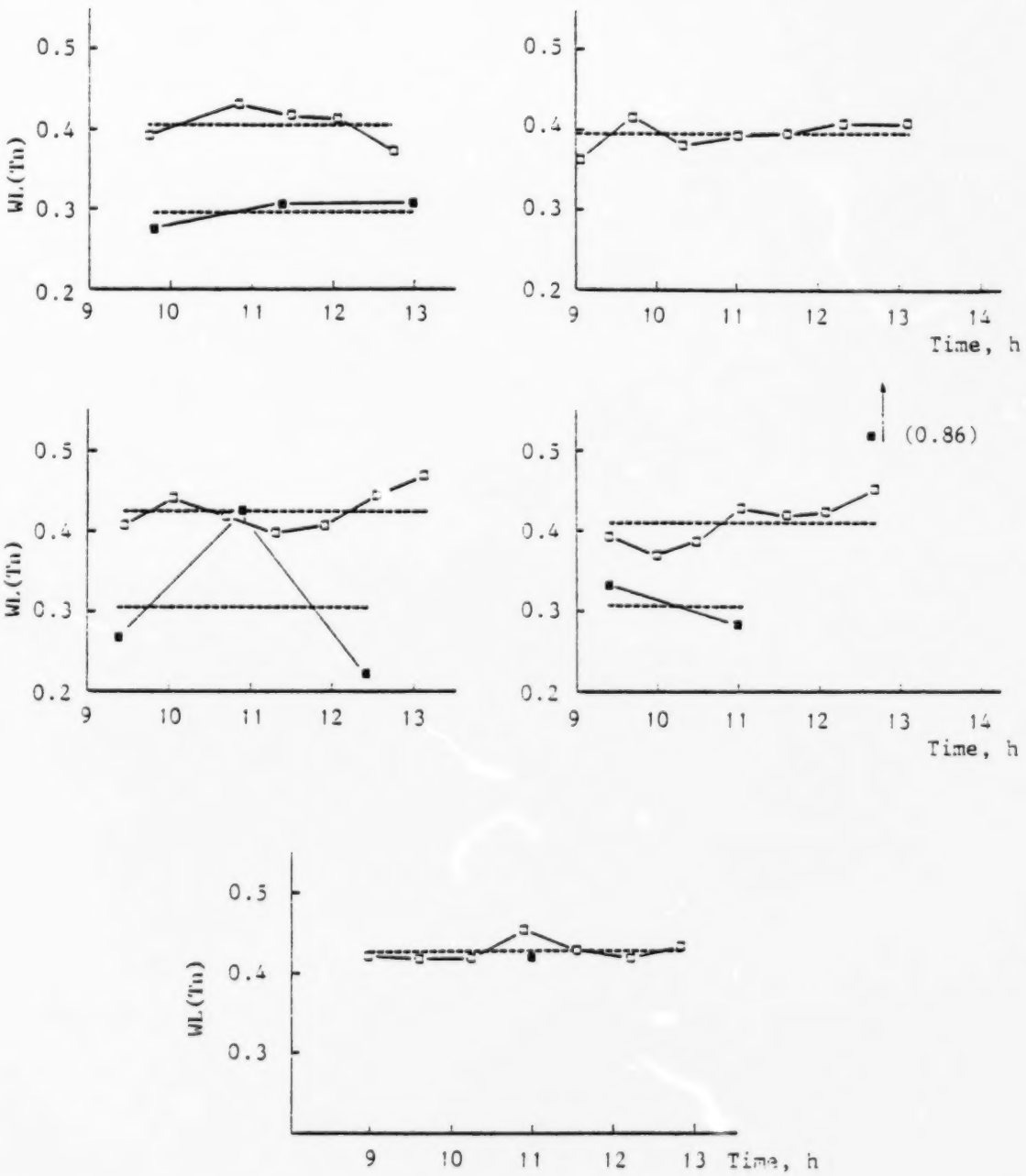

Fig. 14 - WL(Tn) versus time for the WL-1000C (Rn/Tn α-spectroscopy, -■-) and grab-sampling (-□-). Broken lines represent the WL(Tn) daily average for the corresponding method used. Measurements were carried out in an underground uranium mine.

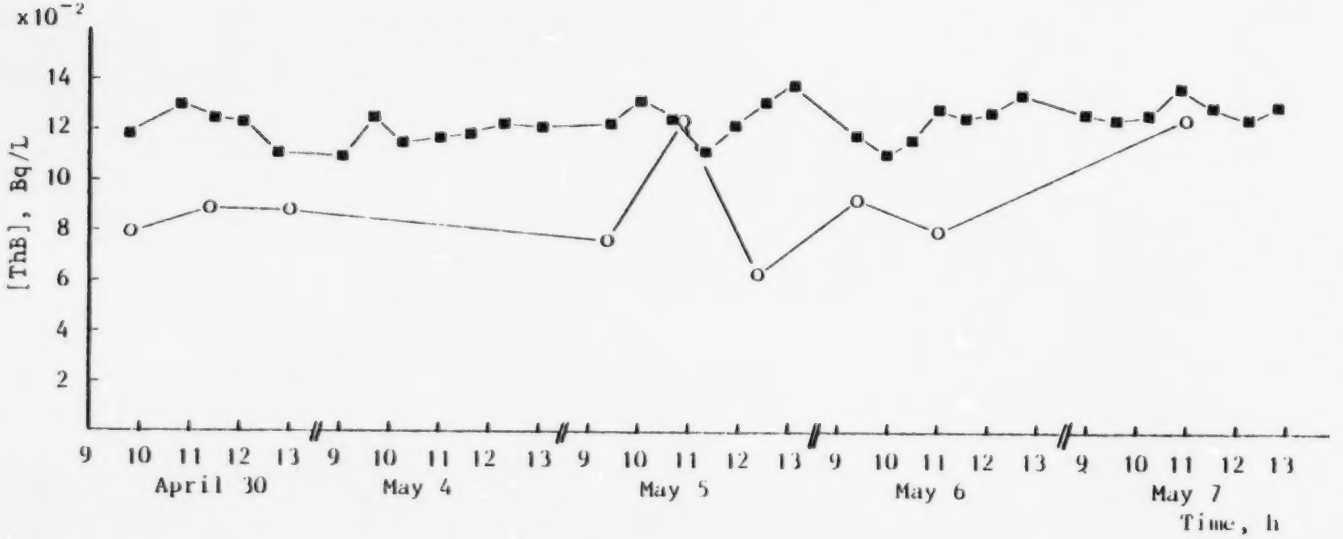

Fig. 15 - ThB concentration versus time for the WL-1000C (Rn/Tn α-spectroscopy, -O-) and grab-sampling (-■-). Measurements were carried out in an underground uranium mine.

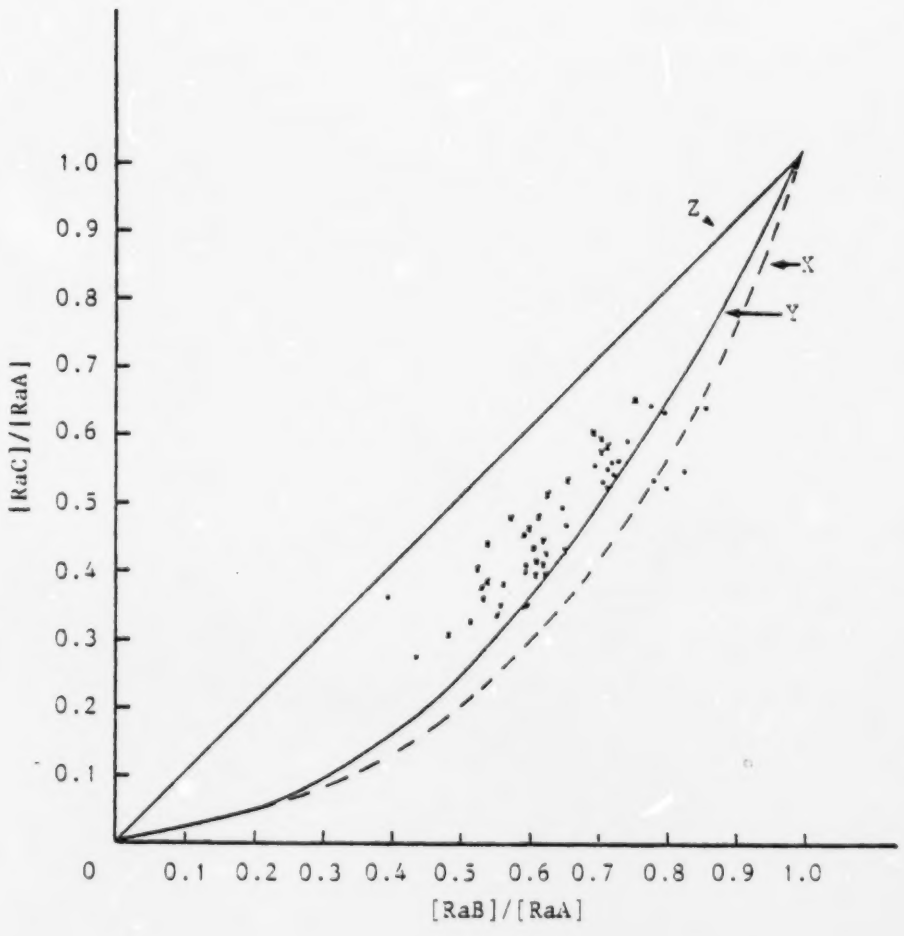

Fig. 16 - Experimental ratio [RaC]/[RaA] versus experimental ratio [RaB]/[RaA] obtained with the WL-1000C (Rn α-spectroscopy, dots) and the Thomas-Tsivoglou method (crosses) on a graph showing the theoretical limiting boundaries of three mine models: the mine tunnel (curve Y), the isolated system (curve X) and a mine model consisting of the mixing of 'young' and 'old' air (curve Z).

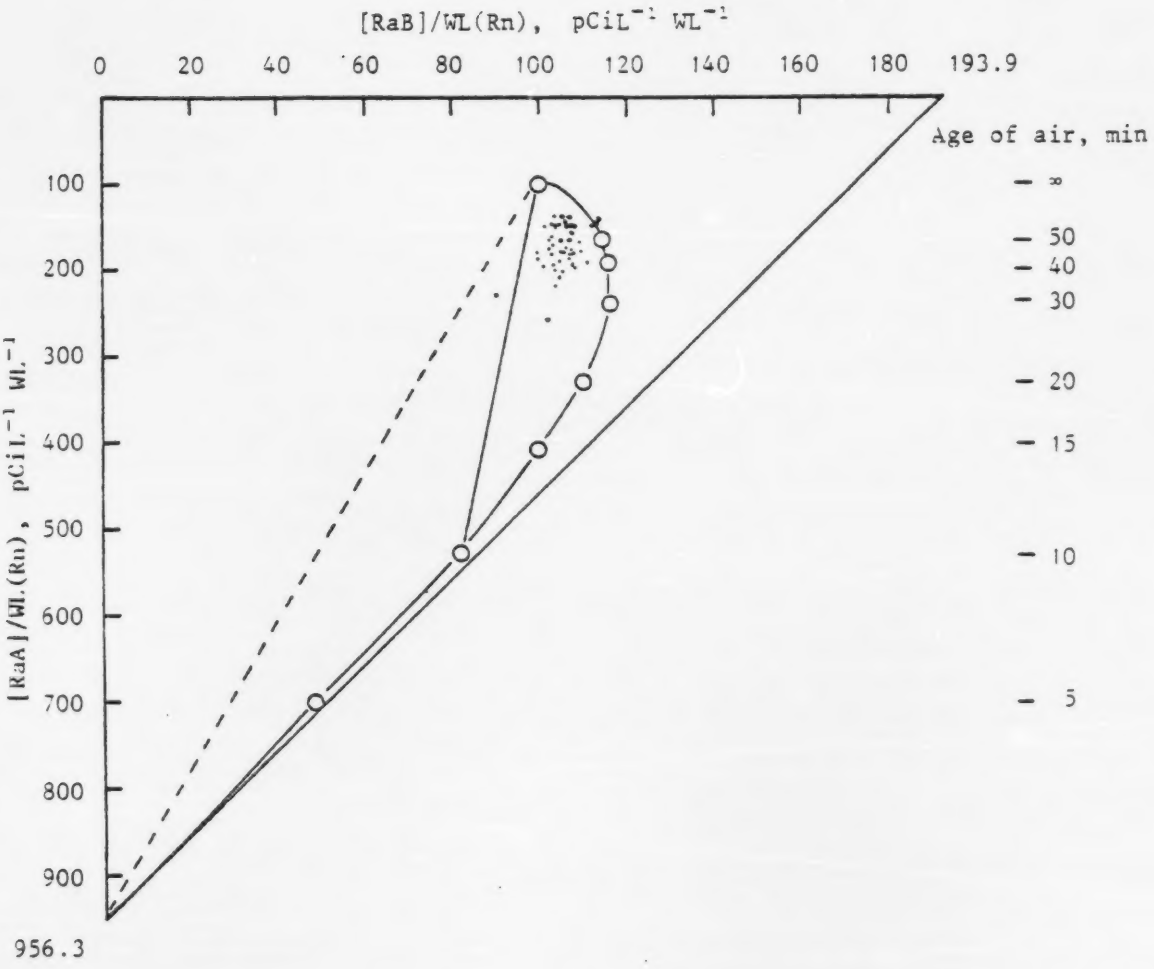

Fig. 17 - Experimental ratio [RaA]/WL(Rn) versus experimental ratio [RaB]/WL(Rn) obtained with the WL-1000C (Rn α-spectroscopy, large dots) and the Thomas-Tsivoglou method (small dots) on a graph showing the theoretical limiting boundaries of the above ratios for the isolated mine model. Also shown on the right hand side are the ages of air corresponding to the theoretical ratios indicated by large empty circles.

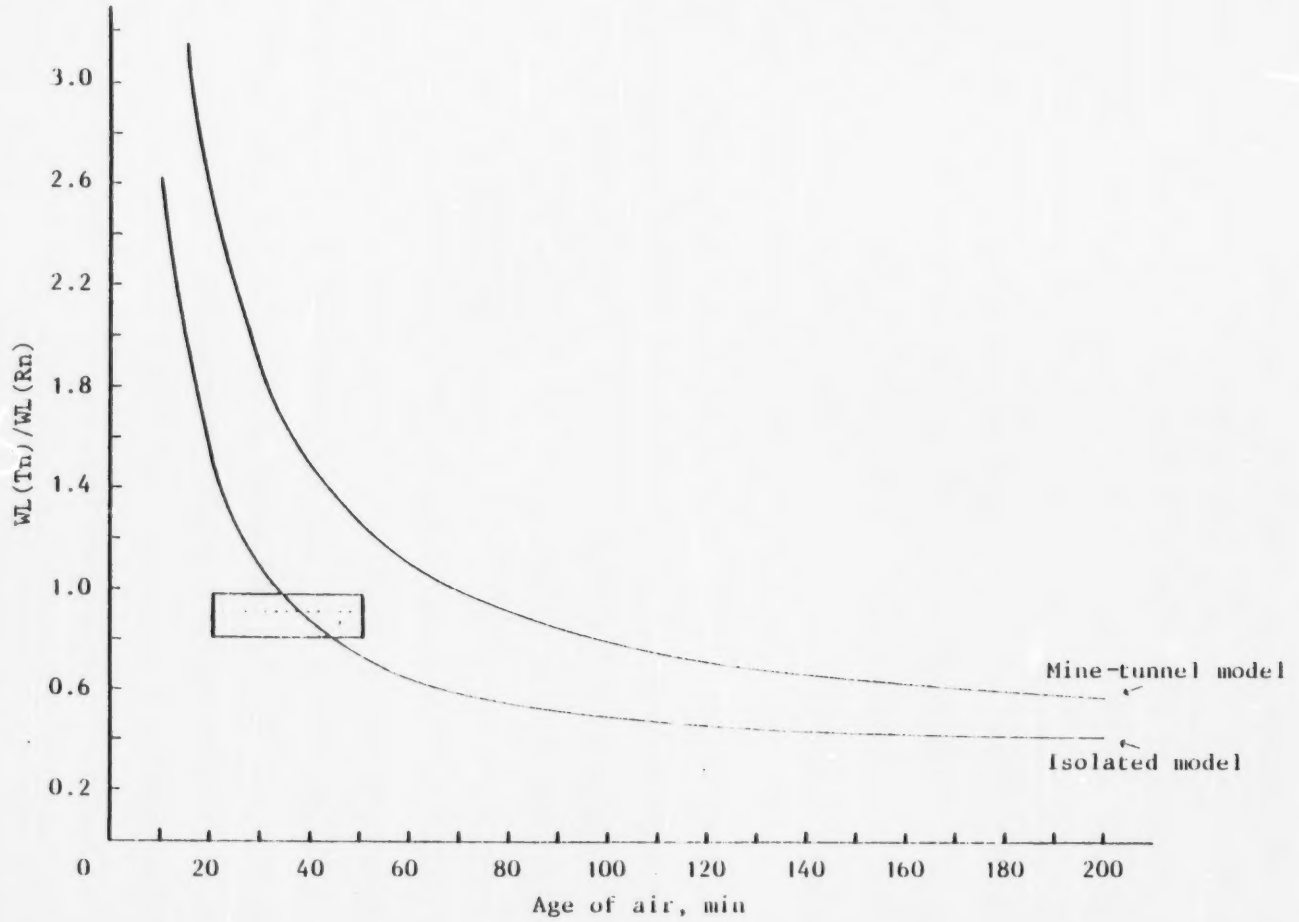

Fig. 18 - Theoretical ratio WL(Tn)/WL(Rn) versus age of air for the mine-tunnel model and the isolated model. The cross-hatched area represents the range of experimental values for the ratio WL(Tn)/WL(Rn) and age of air obtained from Table 1 and Fig. 16 and 17, respectively.

and experimental values of the ratios [RaB]/[RaA] and [RaC]/[RaA]. (Note: the Th-232/U-238 gram ratio used to calculate WL(Tn)/WL(Rn) have been assumed to be unity, an approximate average value for uranium mines in the Elliot Lake area).

Figures 1 and 2 show a series of experiments conducted at low and moderate WLs, i.e., from 0.01 WL to about 1 WL. It can be seen that in general, good qualitative agreement, i.e., WL-profile versus time, is obtained with all the methods and instruments used. In quantitative terms, however, best agreement was found between the Pylon WL-1000C and the Harshaw-WLM than between either of these instruments and the EDA WLM-300 and the Markov method. The measurements with the Pylon WL-1000C included the Rolle method and a short programmable, version of an α-spectroscopy method (15,23). The measurements with the EDA WLM-300 shown in Fig. 1 were done with an early sampling head design which exhibited plate-out problems (28,29). However, EDA Instruments has recently redesigned the sampling head and the results obtained have been found to agree quite well with grab-sampling data as shown in Fig. 7 to 9. In general, the Markov method gave significantly higher values for WL(Rn) than the other methods and instruments used.

Radon daughter concentrations corresponding to the test shown in Fig. 2, obtained with the WL-1000C and Harshaw-WLM, are shown in Fig. 3, 4 and 5. Figure 3 also includes [RaA] data determined by the Markov method. As with the tests corresponding to Fig. 1 and 2, good qualitative agreement was found, but significant quantitative discrepancies were observed for different instruments. Best agreement was obtained for [RaB], see Fig. 4. Substantial differences were obtained for [RaA] and [RaC], see Fig. 3 and 5.

The disagreement observed between the different instrumentation tested and methods used can partly be ascribed to the rapidly changing radiation conditions of the tests compounded with the different sampling

times of the several methods used, and the fact that sampling was not conducted simultaneously with all the instrumentation.

A further series of measurements carried out in a newly designed, better controlled, large radon room gave significantly closer agreement (within about 10-15%) between the different variables of interest than that obtained in previous measurements (see Fig. 6 to 9). In this series of measurements a new sampling head for the EDA WLM-300 was used. Notice that because of the time integrating nature of the EDA WLM-300 the values for WL(Rn) as determined by the instrument lag behind grab-sampling measurements by about 60 min. The reason for this has been discussed elsewhere (28,29).

Figures 10 to 13 show that consistently higher values for WL(Rn), [RaA], [RaB] and [RaC] were obtained by grab-sampling using the Thomas-Tsivoglou method than with the Pylon WL-1000C. The discrepancy found for WL(Rn) and [RaA] ranged approximately from 5% to over 30%, although the average was in the 10% to 20% range. Better agreement for [RaB] and [RaC] between grab-sampling and the Pylon WL-1000C was found as shown in Fig. 12 and 13. Pylon data shown in these figures were obtained using two α-spectroscopy methods which enable the determination of the radon progeny and radon daughter/thoron daughter mixtures, respectively. From the data shown in Fig. 10 to 13, it may be concluded that the main contribution to the discrepancy in WL(Rn) arises from uncertainties in the determination of [RaA].

Figures 14 and 15 show that significantly higher results for WL(Tn) and [ThB] were found by grab-sampling using a total gross α-count method (30) than with the Pylon WL-1000C. Grab-sampling data were over 30% higher than that obtained with the instrument. As no information is available on the α-spectroscopy analytical procedures programmed in the instrument it is not possible to analyze the data of Fig. 10 to 15 any further.

Figures 16 and 17 show that the experimental data obtained in the underground tests are within the theoretical boundaries of the mine models referred to above. These graphs permit the calculation of the age of mine air for the particular mine model used from the ratios [RaB]/[RaA] and [RaC]/[RaA], Fig. 16 (4,25), or from the ratios [RaA]/WL(Rn) and [RaB]/WL(Rn), Fig. 17 (10,26). From Fig. 17 an approximate range of values for the age of mine air from 20 min to 50 min is obtained.

The cross-hatched area of Fig. 18 indicates the range of experimental values for the ratio WL(Tn) /WL(Rn) and the age of mine air obtained from Fig. 17. Fair to good agreement is found for the isolated mine model. The mine tunnel model predicts higher values for the ratio WL(Tn)/WL(Rn) than the isolated mine model for the same age of mine air.

The summary of experimental radiation data and meteorological data obtained during the underground test (see Tables 1 and 2) shows that fairly constant conditions prevailed throughout the underground tests. Hence, discrepancies between the different methods and instruments used cannot be attributed to changing conditions in the underground environment during the sampling periods or plate-out phenomena in sampling heads, as the aerosol concentration was fairly high, particularly the diesel particulate contribution.

CONCLUSIONS

Significant differences between the Pylon WL-1000C and other instrumentation were found when compared with conventional non-automated, grab-sampling by the Thomas-Tsivoglou, Kusnetz and Markov methods.

Discrepancies were larger when sampling took place under rapidly changing radiation conditions. This can be partly explained as different methods and instrumentation use different sampling periods, and sampling for all instruments was not conducted simultaneously. Furthermore, the measurement

Table 1 - Summary of some grab-sampling radiation data (daily average) obtained during 5 day-shifts in an underground uranium mine.

Date	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	[RaA] (Bq/L)	[RaB] (Bq/L)	[RaC] (Bq/L)	[ThB] (Bq/L)	[ThC] (Bq/L)	1:X:Y*	$\frac{[ThC]}{[ThB]}$
April 30	0.49±0.03	0.41±0.02	0.83±0.1	2.89±0.44	1.93±0.19	1.46±0.07	0.086±0.005	0.041±0.006	1:0.67:0.5	0.47
May 4	0.45±0.03	0.39±0.02	0.87±0.07	3.01±0.44	1.77±0.15	1.28±0.10	-	-	1:0.59:0.42	-
May 5	0.43±0.03	0.43±0.02	0.98±0.13	2.97±0.33	1.71±0.14	1.19±0.16	0.088±0.032	0.037±0.005	1:0.58:0.40	0.42
May 6	0.46±0.02	0.41±0.03	0.88±0.05	3.04±0.13	1.80±0.13	1.30±0.13	0.087±0.01	0.040±0.01	1:0.59:0.43	0.28
May 7	0.49±0.02	0.43±0.01	0.87±0.04	3.22±0.42	1.91±0.10	1.39±0.11	0.125	0.032	1:0.59:0.43	0.25

* 1 = [RaA]/[RaA] ; X = [RaB]/[RaA] ; Y = [RaC]/[RaA]

Table 2 - Summary of some meteorological data (daily average) obtained during 5 day-shifts in an underground uranium mine.

Date	Temperature [°C]	Barometric Pressure [kPa]	Relative Humidity %
April 3	18.75±1.77	107.02±0.13	-
May 4	16.11±0.25	106.84±0.07	82.67±0.44
May 5	16.46±0.73	106.35±1.07	83
May 6	16.21±0.37	105.38±0.11	89
May 7	16.76±0.21	105.05±0.04	90

accuracy depends on the method used. Under more constant radiation conditions the agreement is improved. Appreciable discrepancies were found for the thoron progeny under all test conditions.

Additional potential sources of error include:

a) Sampling flow rate variation during the sampling period. (Note: except for the grab-sampling instrumentation used, neither of the tested instruments, including the Pylon WL-1000C, Harshaw-WLM and EDA WLM-300, have sampling flow rate monitoring capabilities);

b) Air flow leaks in the sampling head depending upon the particular mechanism used to 'hold' the sampling filter to the filter holder;

c) Different sampling flow rates used by different instruments, e.g., ranging from 1 L/min for the EDA WLM-300 to about 20 L/min for the Harshaw-WLM (the Pylon WL-1000C sampled at a rate of about 4 L/min. Grab-sampling was done at about 6 L/min).

It should be indicated that the discussion and conclusions drawn above apply equally well to both the instrumentation under technical evaluation and the grab-sampling methods used to evaluate this instrumentation. Hence, the discrepancies observed do not necessarily reflect any fault of the instruments tested. From the experimental data collected taking into account the wide range of environmental conditions of the tests one may conclude that, in general, the agreement between conventional grab-sampling and the Pylon WL-1000C is good. Furthermore, the instrument performed satisfactorily under a wide variety of meteorological and environmental conditions including high relative humidity and high diesel particulate and dust concentrations. Occasional, although rare, electronic failure was encountered under underground conditions. The Pylon WL-1000C is now being tested at tailings sites to determine its response to extreme surface environmental conditions including

high fine-dust concentrations.

There are a number of suggestions that we would like to make to further improve the response and characteristics of the instrument. These are:

1. The sampling head should incorporate a flowmeter to monitor sampling flow rate during sampling;
2. An improved 'clamping' mechanism to hold the filter in the sample holder would be desirable. It is our suspicion that some of the differences observed are due to air-leaks between the filter and filter holder. As there is no means at present to monitor the sampling flow-rate, no indication of air leaks or constancy of flow during sampling is possible;
3. The slot which permits insertion of the sample in position facing the detector should be provided with a lid so that when the face of the instrument is exposed, but not counting, dust and other unwanted substances will not go in. It is important to protect the detector against fines, moisture and dirt which may damage the detector in addition to inducing faulty electronic contacts;
4. The keyboard on the face of the instrument should preferably be of the membrane-touch type, which is sealed against environmental agents. The present keyboard is particularly vulnerable to dust, moisture and other unwanted airborne physical and chemical agents;
5. An enlarged memory capability for data storage would be quite useful to store all data gathered during the shift so that it could be retrieved at the end of the day by means of an external printer. (Note: the Pylon WL-1000C already has a standard RS-232 interface, but the use of an external printer is limited to print-out the data after each run.)
6. A better indication on the filter and detector slot as to the way the filter should be inserted would simplify the operation;

7. There is an urgent need for adequate standard radon daughter and thoron daughter sources to determine accurately the α-counting efficiency of the instrument's detector. Although sources have been developed for such purposes we encountered some difficulties in their use.

We are happy to learn that Pylon has already planned to introduce some of the modifications and suggestions indicated above. We would also like to acknowledge that Pylon was already aware of some of the items above prior to our discussion with members of the staff.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance provided by Dr. Vandrish to conduct this work and for many helpful discussions throughout. We would also like to thank Mr. Wheatley for so kindly agreeing to let us have the instrument with which the data presented here was obtained. We also acknowledge with thanks the assistance of Messrs. Elliot and Ryan in different phases of this investigation. The above individuals are all staff members of Pylon Instruments (Ottawa). Thanks are also extended to Mr. Chakravatti (Denison Mines) for making arrangements for us to sample in Denison premises.

REFERENCES

1. Markov, K.P., Ryabov, N.V. and Stas, K.N., "A rapid method for estimating the hazard associated with the presence of radon daughter products in air"; At Ehnerg, vol 12, p 315; 1962.

2. Kusnetz, H.L., "Radon daughters in mine atmospheres"; Am Ind Hyg Assoc J, vol 17, p 1; 1956.

3. Kusnetz, H.L., "Radon daughters in mine atmospheres - a field method for determining concentrations"; Ind Hyg Quarterly; March 1956.

4. Rolle, R., "Improved radon daughter monitoring procedure"; Am Ind Hyg Assoc J, pp 153-160; March/April 1969.

5. Rolle, R., "Rapid working level monitoring"; Health Physics, vol 22, pp 233-238; 1972.

6. Tsivoglou, E.C., "Quantitative description of successive transformations in atmospheric samples"; Dissertation; Ohio State University; 1953.

7. Tsivoglou, E.C., Ayer, H.E. and Holaday, D.A., "Occurrence of non-equilibrium atmospheric mixtures of radon and its daughters"; Nucleonics, vol 11, no 9, pp 40-45; 1953.

8. Thomas, J.W., "Measurement of radon daughters in air"; Health Physics, vol 23, pp 783-789; 1972.

9. Lockhart, L.B., Patterson, R.L. and Hosler, C.R., U.S.N.R.L. Report 6229; 1965.

10. Droullard, R.F. and Holub, R.F., "Continuous working level measurements using alpha or beta detectors"; Report of Investigations RI 8237; U.S. Bureau of Mines; 1977.

11. Holmgren, R.M., "Working levels of radon daughters in air determined from measurements of RaB and RaC'"; Health Physics, vol 27, pp 141-145; 1974.

12. Horwood, J.L., unpublished data.

13. Kerr, G.D., "Measurement of radon progeny concentrations in air by alpha-particle spectrometry"; Oak Ridge; Technical Report ORNL-TM-4924; 1975.

14. Martz, D.E., Holleman, D.F., McCurdy, D.E. and Schiager, K.J., "Analysis of atmospheric concentrations of RaA, RaB and RaC by alpha spectroscopy"; Health Physics, vol 17, pp 131-138; 1969.

15. Tremblay, R.J., Leclerc, A., Mathieu, C., Pepin, R. and Townsend, M.G.,

"Measurement of radon progeny concentration in air by α-particle spectrometric counting during and after air sampling"; Health Physics, vol 36, pp 401-411; 1979.

16. Schroeder, G.L. and Evans, R.D., "Some basic concepts in uranium mine ventilation, radium and mesothorium poisoning and dosimetry and instrumentation techniques in applied radioactivity"; Annual Progress Report from Massachusetts Institute of Technology; MIT-952-5 (May 1968); also see MIT-952-6 (1969).

17. Groer, P.G., Keefe, D.J., McDowell, W.F. and Selman, R.F., "An instant working level meter with automatic radon-daughter readout"; Final Report from Argonne National Laboratory (Argonne, Illinois, U.S.A.) to U.S.B.M. August 1974.

18. Rolle, R., "Determination of radon daughters on filters by a simple liquid scintillation technique"; Am Ind Hyg Assoc J, vol 31, pp 718-721; Nov/Dec 1970.

19. Hill, A., "Rapid measurement of radon, decay products, unattached fractions and working level values of mine atmospheres"; Health Physics, vol 28, no 4, pp 472-474; April 1975.

20. James, A.C. and Strong, J.C., "A radon daughter monitor for use in mines"; Proc 3rd int Congr IRPA, Washington; pp 932-938; 1973.

21. Groer, P.G., Keefe, D.J., McDowell, W.F. and Selman, R.F., "Development of a prototype instant working level meter with automatic individual radon daughter readout"; Argonne National Laboratory Report PB-249 545 (BuMines OFR 19-76), Jan 1975.

22. Bigu, J., "Monitoring of radiation variables in the underground environment"; CIM Bulletin, vol 74, no 832, pp 83-92; 1981.

23. Coté, P. and Townsend, M.G., "Effect of thoron daughters on radon daughter counting procedures: examination of α- and β-counting methods"; Division

Report MRP/MSL 79-39(TR); CANMET, Energy, Mines and Resources Canada; 1979.

24. Grenier, M. and Bigu, J., "Experimental procedure for the determination of counting efficiency and sampling flow rate of a grab-sampling working level meter"; Division Report MRP/MRL 82- (TR); CANMET, Energy, Mines and Resources Canada; 1982.

25. Rolle, R., "Radon daughters and age of ventilation air"; Health Physics, vol 23, pp 118-120; 1972.

26. Holub, R.F. and Droullard, R.F., "Evaluation of various radon daughter measurement methods"; Proc Workshop on Methods for Measuring Radiation in and Around Uranium Mills, Albuquerque, New Mexico, May 23-26, 1977; E.D. Harvard (Ed.) vol 3, no 9, pp 197-219; 1977.

27. Holub, R.F. and Droullard, R.F., "Radon daughter mixture distributions in uranium mine atmospheres"; Report of Investigations RI 8316; U.S. Bureau of Mines; 1978.

28. Bigu, J. and Grenier, M., "Calibration of environmental monitors operating on time integrating principles for radon/thoron decay products"; Division Report MRP/MRL 82-36(TR); CANMET, Energy, Mines and Resources Canada; 1982.

29. Bigu, J. and Grenier, M., "Technical evaluation of a radon daughter continuous monitor in an underground uranium mine"; Division Report MRP/MRL 82- (TR), CANMET, Energy, Mines and Resources Canada; 1982.

30. Rock, R.L., "Sampling mine atmospheres for potential α-energy due to presence of radon/thoron daughters"; Information Report IR 1015, U.S. Dept. of the Interior; 1970.

POOR

QUALITY

ORIGINAL